# MAPPING CORAL REEF BOTTOM-TYPES AND BATHYMETRY USING COMPACT AIRBORNE SPECTROGRAPHIC IMAGER (CASI) DATA

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## 1. INTRODUCTION

Resource inventory and mapping is one of the most common applications associated with the remote sensing of coral reefs. Given the pressing context of global climate change, remote sensing could play a vital role in the detection of live coral/algal dominated community phase shifts [1], and locate both degenerating reefs which need special attention, as well as reefs resisting change which may provide refuges and sources for larvae/reseeding.

High spatial- and spectral-resolution sensors, such as the Compact Airborne Spectrographic Imager (CASI), can theoretically detect the subtle spectral differences between coral reef bottom-types [2-4], yet the link between spectral studies and actual image classification has not been thoroughly investigated. Studies mapping marine environments using CASI imagery have used image data for classification either through unsupervised [5] or supervised methods [6, 7], although none have used spectral reflectance data gathered *in-situ* to supervise the classification. Using spectral libraries or look-up tables to supervise image classification has the potential to automate coral reef mapping procedures independent of ancillary field surveys [8, 9].

The aim of the study was to collect *in-situ* spectral reflectance signatures, convert them to be compatible with high spatial resolution airborne or satellite image data, and use them to supervise image classification and create maps of coral reef bottom-types. In particular, the focus was on the ability to map live coral, abiotic turf (dead coral substrate with an algal turf covering) and macroalgae, as these communities could be used to indicate reef status [1].

## 2. METHODOLOGY AND RESULTS

This study used an established mapping algorithm, Spectral Angle Mapper (SAM), which allowed bottom-type and depth to be mapped simultaneously. SAM has previously been used to map coral reef features using Hyperion image data [9, 10], a sensor with high spectral resolution (196 bands) and moderate spatial resolution (30 m pixel size). We further developed this approach using CASI image data which features a more appropriate spatial resolution (1.0 m pixel size) when considering the bottom-types being mapped and the pure endmember spectral reflectance library used.

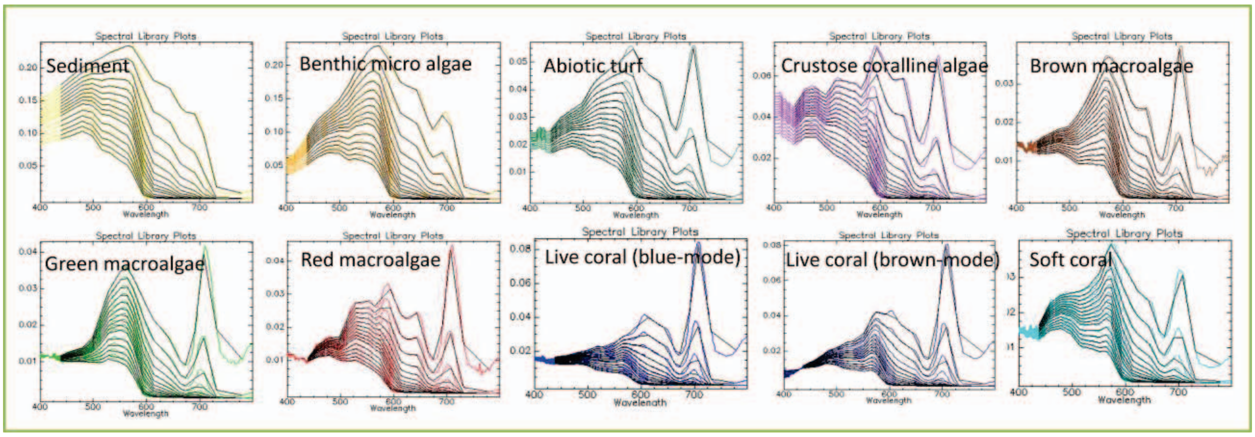

Figure 1. Subsurface remote sensing reflectance curves for each bottom-type at depths 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, 7.0, 8.0, 9.0, and 10.0 m. The coloured lines represent the full resolution (400-800nm) spectra, the black lines represent the correspond curves transformed to the spectral sensitivity of the CASI sensor.

CASI image data were acquired on 01 and 03 July 2002, capturing the extent of Heron Reef within 45 flight lines. Data were collected at a 0.99 m pixel spatial resolution, across 19 spectral bands. Extensive pre-processing was undertaken to convert the at-sensor radiance values to subsurface remote sensing reflectance, referenced to UTM WGS84 projection and datum.

Spectral reflectance measurements for 10 coral reef bottom-types (sediment, benthic microalgae, abiotic turf, crustose coralline algae, brown macroalgae, green macroalgae, red macroalgae, live coral (brown-mode), live coral (blue-mode), and soft coral) were measured *in-situ* at Heron Reef in June 2006. To simulate the effect an overlying water column would have on the *in-situ* spectral reflectance signatures, the Hydrolight® 4.2 radiative transfer model was used to create a spectral reference library of remote sensing reflectance just below the water surface (figure 1). The most noticeable effect of the water column was attenuation from 575nm, and less pronounced spectral absorbance features as water depth increases. Some prominent features were either no longer evident or had their waveband position shifted when the full resolution curves were resampled to the CASI band set.

SAM is a classification procedure which focuses on the shape of spectral reflectance curves and is relatively insensitive to illumination. A multi-rads SAM classification was run using the reference spectral library shown in figure 1. Additionally, based on the spectral reflectance properties of sediment, it was decided to use SAM to classify sediment in deeper waters, and a density slice using band 4 (498.6 nm) to classify shallow water sediment based on its relatively high magnitude of reflectance. The depth classes within each bottom-type were merged to produce a final map of 10 bottom-types (figure 2a).

Field validation data was collected in April 2001 and November 2002, capturing 2292 geo-located photographs on snorkel-, scuba- and boat-based transects. The classification image displayed a good agreement with validation data collected on the snorkel- and boat-based transects. In comparison to validation data collected on scuba (at depths greater than 8.0 m), the image classification was poor. This highlighted a depth limitation of the mapping approach to waters shallower than 8.0 m.

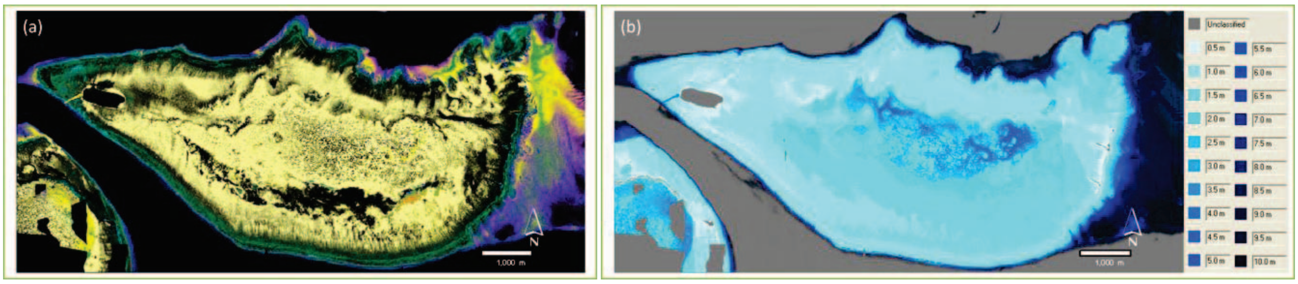

Figure 2. Classification image of (a) bottom-types on Heron Reef, with colours corresponding to bottom-types shown in figure 1; and (b) estimated bathymetry on Heron Reef.

Unclassified pixels in areas past the reef slope were expected, as the reference spectral reflectance library only contained signatures modelled to 10.0 m water depth. Unclassified pixels in areas where the water column was known to be less than 10.0 m were likely due to a mixture of reef bottom-types within those pixels, compared to the pure endmember spectral reflectance signatures used to create the reference library. This showed that SAM worked well in only matching the signatures of pixels dominated by a single bottom-type, which have distinctly different signatures to mixed assemblage spectra [11].

Merging pixels classified with the same depth, regardless of bottom-type composition, created a bathymetric map of the site in 0.5 m intervals from 0.5-10.0 m depth (figure 2b). The map displayed accordance with known geomorphic features. It is also worth noting that the bottom-type did not influence the bathymetry map, as shown in the different depths for sediment surrounding coral bommies in the lagoon, and constant depths for differing bottom-types near the benthic microalgae in the south-east corner of the lagoon.

To validate the bathymetric output image, boat-based depth sounding measurements collected in 2007 were used. These measurements surveyed a range of depths and geomorphic features across the reef slope, crest, lagoon, patch bommies, reef flat and harbour. Plotting the estimated water column depth from the SAM classification against the sonar depths resulted in a regression slope with an $R^2$ value of 0.928.

## 3. CONCLUSIONS AND RECOMMENDATIONS

This study was able to simultaneously map 10 bottom-type classes along with bathymetry on Heron Reef. The maps closely matched field validation data and knowledge of the site, including areas dominated by live coral and macroalgae. It is encouraging for potential applications monitoring and managing reef status, that a spectral reflectance difference between macroalgae, abiotic turf, and live coral was detectable by the CASI band set and SAM mapping approach. Provided that spectral reflectance signatures are available, this approach allows image classification to occur independent of ancillary field data, which is beneficial for the challenging locations and environments where coral reefs occur. To be able to obtain such spatial data has the potential to aid in the monitoring and management of coral reefs.

The method was useful for mapping pixels dominated by a single bottom-type in water depths less than 8.0 m. Pixels which were not dominated by a single bottom-type were not classified, as no spectral reflectance signatures were available to characterise them, and future studies should consider adding mixed spectra to the reference spectral library. Understanding and utilising the optical properties of coral reef bottom-types and environments, particularly the effect of the water column, is necessary to progress multi-temporal remote sensing of coral reefs.

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